Chemical Nomenclature for an Introductory Chemistry Course: A Tutorial Rules & Drills with Answers

Table of Contents

Chemical Nomenclature for an Introductory Chemistry Course: A Tutorial
Rules & Drills with Answers

For beginning students, the study of nomenclature (system of naming chemicals) can seem impossibly complex. For that reason, the rules and drills presented here are broken down into Units, and it is not advisable to study all the units at one sitting, but you should take it one unit at a time. If you are not able to spread out your work over several days, you should at least take a break in between units.

Unit I: Chemical Symbols of Some Common Elements

You must first learn the symbols of some common elements. Your instructor may have different requirements on which elements you must learn. The ones listed below are the ones you you are expected to know in an introductory chemistry course. You might want to put them on flash cards. ***You should drill yourself one way or another before you proceed to the next unit***.

Notice that the elements below are boxed together in groups, some elements appearing in more than one group. My suggestion is you learn them in groups, in this order: Elements #1 through 18, Group IA, IIA, VIIA, VIIIA, Common Transition Elements, and finally, Other Common Elements. If you have trouble with spelling, you'll find it easier to learn correct spelling if you copy the names several times as you sound it out. If you think this is too much work, then you are taking the wrong course. Studying chemistry takes work, regardless of how smart you are.

COMMON ELEMENTS: NAMES AND SYMBOLS

Learn the names (with correct spelling) and symbols of the elements listed below (no need to memorize numbers). Note that the symbols are capitalized. If the symbol consists of two letters, *only* the first letter is capitalized.

Elements # 1 - 18		**Group IA**		**Group VIIA**	
H	hydrogen	H	hydrogen	H	hydrogen
He	helium	Li	lithium	F	fluorine
Li	lithium	Na	sodium	Cl	chlorine
Be	beryllium	K	potassium	Br	bromine
B	boron			I	iodine
C	carbon				
N	nitrogen				
O	oxygen				
F	fluorine	**Group IIA**		**Group VIIIA**	
Ne	neon				
Na	sodium	Be	beryllium	He	helium
Mg	magnesium	Mg	magnesium	Ne	neon
Al	aluminum	Ca	calcium	Ar	argon
Si	silicon	Sr	strontium	Kr	krypton
P	phosphorus	Ba	barium	Xe	xenon
S	sulfur	Ra	radium	Rn	radon
Cl	chlorine				
Ar	argon				

Common Transition		Other Common Elements			
Cr	chromium	As	arsenic	U	uranium
Mn	manganese	Sn	tin	Pu	plutonium
Fe	iron	Pb	lead		
Co	cobalt	Ag	silver		
Ni	nickel	Hg	mercury		
Cu	copper				
Zn	zinc				

Elements that you should be able to provide names or symbols are highlighted in RED.
The ones in BLUE you will learn a little later in the semester.

	1 IA	2 IIA	3 III B	4 IV B	5 V B	6 VI B	7 VIIB	8 VIII B	9 VIII B	10 VIII B	11 I B	12 II B	13 III A	14 IV A	15 V A	16 VI A	17 VIIA	18 VIII A
1	1 H																1 H	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

Lanthanides:	58 *Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides:	90 **Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Drill A: Nomenclature of Elements

This is a self-test, since you can easily look up answers yourself. After you have drilled yourself on the symbols and spelling of the elements listed above, take this as a practice test.

Name	Symbol	Symbol	Name
chlorine		S	
calcium		K	
arsenic		Fe	
mercury		Na	
copper		P	

Remember not to proceed to the next unit until you have ***studied*** *Unit I.*
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Unit II: Nomenclature of Pure Elements

The term, "***Pure Elements***", **refers to elements when they are *not* combined with other elements such as in compounds. Certain pure elements exist in clusters, joined by covalent bonds, called *molecules*. For example, pure nitrogen exists as N_2 rather than N. When nitrogen is not part of a compound, it is also referred to as "*free nitrogen*" or "nitrogen in its elemental state".**

Formulas of Pure Elements (Note where these elements are located on the Periodic Table.)

Diatomic molecules:

		H_2
N_2	O_2	F_2
		Cl_2
		Br_2
		I_2

Other molecular elements:

P_4	S_8

***Monatomic elements: with* a few exceptions, all others are monatomic (e.g. He, Ne, Fe, Al are monatomic).**

Exceptions: **Elemental oxygen also exists in a less stable form as O_3 (ozone).**
Although we usually write C for pure carbon, it usually exists as an extended network of various types. Refer to your textbook if you are interested in these various *allotropes* of carbon. We will simply write C as if it were monatomic.

Physical States of Pure Elements

gases:

		H_2	He
N_2	O_2	F_2	Ne
		Cl_2	Ar
			Kr
			Xe
			Rn

liquids: **Br_2 and Hg**

solids: **with a few exceptions, all others are solids (e.g. K, Fe, Co, Sn, U are solids.)**

Drill B: Formulas and Physical States of Pure Elements

To make the best use of the drills in this tutorial, you should first study and memorize the above rules on the formulas and physical states of pure elements. Then write down the answers to the drill (rather than keeping them in your head). Answers are provided in a later part of this exercise, but do not check your answers until you have written down your answers to the entire drill. This takes discipline, but it would do you no good to flip to the answers without having put thought and time in working out the answers first.

Using only a periodic table, give the formulas and physical states of the elements specified. Specify the physical states with (*g*), (*l*) or (*s*). Example: fluorine = F_2 (*g*)

chlorine		bromine		sulfur	
argon		phosphorus		lead	
nitrogen		krypton		element #109	
chromium		mercury		arsenic	
strontium		iodine		hydrogen	

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Unit III: Nomenclature of Monatomic Ions (Simple Ions)

"Simple Ions" refer to ions that are charged *atoms*, as opposed to charged *molecules*. They are therefore also known as *monatomic ions*.

Unit IIIA: Nomenclature of Monatomic Anions

A negatively charged ion is known as an "anion". Its name ends with *–ide*. For example, the chlorine ion is named *chloride,* and the phosphorus ion is named *phosphide*. The charge of a monatomic anion can be determined by its Group number in the periodic table. An anion in Group VIIA has a charge of 1–. An anion in Group VIA has a charge of 2–, etc. See Table below.

NAMES OF MONATOMIC ANIONS (SIMPLE ANIONS)			
IVA	**VA**	**VIA**	**VIIA**
			H^- hydride
C^{4-} carbide	**N^{3-} nitride**	**O^{2-} oxide**	**F^- fluoride**
	P^{3-} phosphide	**S^{2-} sulfide**	**Cl^- chloride**
	As^{3-} arsenide		**Br^- bromide**
			I^- iodide

Unit IIIB: Nomenclature of Monatomic Cations of Fixed Charges

A positively charged ion is known as a *cation*. Cations in Group IA, IIA and aluminum have *fixed* charges (i.e. nonvariable charges). Those in Group IA always have a charge of **1+**, and those in Group IIA, a charge of **2+**. The aluminum ion always has a charge of **3+**. The name of a monatomic cation of fixed charge is merely the name of the element followed by the word "ion". Thus Na^{+} is "sodium ion". It is *not necessary* to specify the charge since it is nonvariable. There are a few other cations* that also fall in this category, but we will keep it simple for now and stick with just Groups IA, IIA and aluminum.

NAMES OF MONATOMIC CATIONS (SIMPLE CATIONS)		
IA	**IIA**	**IIIA**
H^{+} **hydrogen ion**		
Li^{+} **lithium ion**	Be^{2+} **beryllium ion**	
Na^{+} **sodium ion**	Mg^{2+} **magnesium ion**	Al^{3+} **aluminum ion**
K^{+} **potassium ion**	Ca^{2+} **calcium ion**	
	Sr^{2+} **strontium ion**	
	Ba^{2+} **barium ion**	
	Ra^{2+} **radium ion**	

* Other common cations that have fixed charges include the following: Ag^{+}, Ni^{2+}, Zn^{2+}, Cd^{2+}
These do not require Roman numerals, although including Roman numerals would not be incorrect.

Unit IIIC: Nomenclature of Monatomic Cations of Variable Charges

Cations not named above are assumed to be of variable charges. For example iron can exist with various charges, the most common of which are in the form of Fe^{2+} and Fe^{3+}. Their names ***must*** therefore specify the charges. This is done by following the name of the element with the charge in Roman numerals, within parentheses. Fe^{2+} is named *iron(II) ion,* and Fe^{3+} is named *iron(III) ion.* Tin(IV) ion refers to Sn^{4+}. Names based on this system of nomenclature are known as "*Stock names*".

Many of these ions have "*common names*". Of the two most common ions, the one with the lower charge has the ending *–ous*, and that with the higher charge has the ending *–ic*. Thus Fe^{2+} has the common name, of *ferrous ion*. Fe^{3+} has the common name of *ferric ion.* Since some of these names are indeed quite commonly used (as in food labels), it would be wise to be at least familiar with the four common names included in the table below.

Formula	Stock Name	Common Name
Fe^{2+}	iron(II) ion	ferrous ion
Fe^{3+}	iron(III) ion	ferric ion
Cu^{+}	copper(I) ion	cuprous ion
Cu^{2+}	copper(II) ion	cupric ion

Since the ending in the common name specifies the charge, it would be redundant (therefore wrong) to also include the Roman numeral. Thus $\mathbf{Cu^{+}}$ should *not* be named as *cuprous(I) ion.* Incidentally, the ending –ous does <u>not</u> indicate the charge is 1+, nor 2+. The –ous ending indicates the *lower* charge of the two most common charges. In the case of iron, the two common charges are 2+ and 3+, so the *lower* charge would be 2+. Thus ferrous refer to Fe^{2+} rather than Fe^{3+}.

*Note: Most likely your instructor will not require you to learn the <u>common</u> names. (You **<u>do</u>** need to know that Fe^{2+} is the iron(II) ion, but you do not need to know whether it is ferrous or ferric.) Check with your own instructor whether that is so in <u>your</u> class.*

Drill C: Nomenclature of Monatomic Ions
Again, study the rules before taking this as a practice test. ***.*** *<u>Write down</u> your answers and compare them with the answers provided only after you have finished the entire drill. You may use only a periodic table.*

FORMULA	NAME
$\mathbf{Rb^{+}}$	
$\mathbf{Ba^{2+}}$	
$\mathbf{P^{3-}}$	
$\mathbf{Br^{-}}$	
$\mathbf{N^{3-}}$	
$\mathbf{S^{2-}}$	
$\mathbf{Hg^{2+}}$	
$\mathbf{Cu^{2+}}$	
Ca	
$\mathbf{Ni^{2+}}$	

NAME	FORMULA
nitride	
iodide	
oxide	
chromium(III)	
potassium ion	
aluminum ion	
magnesium	
iron(II) ion	
copper(I) ion	
zinc ion	

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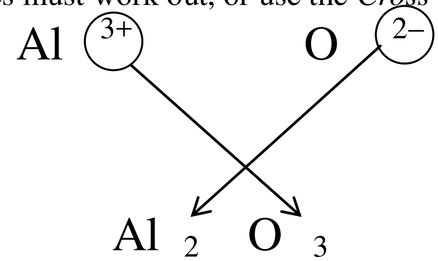
<u>Unit IV: Nomenclature of Ionic Compounds of Monatomic Ions</u>

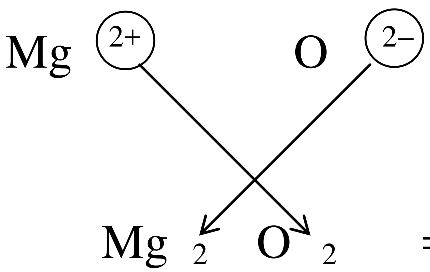
An ionic compound is generally made of one type of cation combined with one type of anion. The formula has no *net* charge even though the ions themselves are charged. Thus, the number of cations and the number of anions present must reflect a net charge of zero. These numbers appear as subscripts, immediately following each element.

For example, $\mathbf{Na^{+}}$ combines with $\mathbf{Cl^{-}}$ to form **NaCl** (net charge of zero, so no charges are shown). When $\mathbf{Na^{+}}$ combines with $\mathbf{O^{2-}}$, however, you will need two $\mathbf{Na^{+}}$ to neutralize the charge of **2–** on the oxygen, to give $\mathbf{Na_2O}$. When $\mathbf{Mg^{2+}}$ combines with $\mathbf{Cl^{-}}$, you will similarly need two $\mathbf{Cl^{-}}$ to neutralize the charge of **2+** on the magnesium, to give $\mathbf{MgCl_2}$. Note that the subscript 2 refers only to the number of Cl, and not the number of Mg. When no subscript shows, it is assumed to be one. Thus, the formula $MgCl_2$ tells us that there is one Mg ion for every two Cl ions. The subscripts show us the *simplest ratio* of cation to anion. (It would be wrong to write Mg_2Cl_4 because 2:4 can be reduced to 1:2.)

When you combine **Al^{3+}** with **O^{2-}**, in order to come up with a net charge of zero, you would need two **Al^{3+}** and three **O^{2-}**, to give Al_2O_3. You can arrive at this answer by simply thinking about how the charges must work out, or use the *Cross Over Method*.



The *Cross Over Method* is merely a fast way to figure out how to make the net charge come out zero. It does ***not*** mean that Al now becomes **2–** and oxygen now becomes **3+**. Note also that in the *Cross Over Method*, the signs (charges) do not cross over (i.e. charges do not appear in the subscript.) Note also that in this method, you must always check that the subscripts are always reduced to the ***simplest ratio***.



= MgO, ***not*** Mg_2O_2 !

Even though there are ions (and charges) present in the compound, we do not show the charges in these formulas. It would be improper to write **$Al^{3+}{}_2O^{2-}{}_3$** or **$Mg^{2+}O^{2-}$**, unless you needed to stress the charges for a special reason.

Unit IVA: Writing Formulas from a Given Name

First figure out the charges of the cation and the anion by examining the name. Then combine the ions in a ratio that gives you a net charge of zero as described above. If you have trouble deciding what the charges are on the ions, *you need to review Unit III !* You should be able to do the drill without using anything but a periodic table.

For example, given the name, tin(II) oxide, you know that the ions are Sn^{2+} and O^{2-}. To write the formula for the compound with Sn^{2+} and O^{2-}, you examine the charges and can see that it will take one Sn^{2+} and one O^{2-} to form a neutral compound.

Let's look at another example. Given the name, tin(IV) oxide, you know that the ions are Sn^{4+} and O^{2-}. In order to form a neutral compound, we must have one Sn^{4+} and <u>two</u> O^{2-}. The formula must therefore be SnO_2.

Now try out the Drill D.

Drill D: Formulas of Ionic Compounds of Monatomic ions

NAME	FORMULA
magnesium fluoride	
lithium sulfide	
calcium nitride	
nickel fluoride	
copper(II) bromide	
chromium(III) sulfide	
tin(II) phosphide	

Unit IVB: Writing Names from a Given Formula

Examine the formula. If the cation belongs in the group that has *fixed charges*, then you just name the cation, followed by the anion, but drop the word "ion" that comes in between. For example NaCl is sodium chloride, and not sodium ion chloride. $MgCl_2$ is magnesium chloride.

Drill E: Writing Names of Compounds with Cations of Fixed Charges

KBr	
Li_2O	
Mg_3As_2	
Na_3P	

If the cation belongs in the group that has variable charges, you must figure out what that charge is from the charge of the anion (which is always fixed). Do ***not*** use the *Cross Over Method* as it may lead to the wrong answer. For example, the formula SnO tells us that Sn must have a charge of **2+** since the oxygen ion is always **2–**. If you used the *Cross Over Method*, you would have erroneously come up with Sn having **1+** charge. The *Cross Over Method* may seem to work, but it works only in some and not *all* cases. So, it would be wiser not to use it at all for going backwards (from formula to name).

Remember that the charge is per ion. Thus Cu_2S tells us that Cu had a charge of **1+,** not **2+**. Since the S ion is always **2–** (Group VIA), the two Cu must have a total charge of **2+**. Thus *each Cu must have* ***1+***.

Drill F: Determining the Charge and Name of the Cation First, Then Name of Compound

Formula	Charge of Cation	Name of Cation	Name of Compound
MnO_2			
PbS			
Cr_2O_3			
K_2S			
$CuCl_2$			
CuO			
Cu_2O			
ZnO			

Check your answers to the above drill before going on. If you have made any mistakes be sure you find out why before you continue to the next drill. If necessary you should review all the previous Units.

Drill G: Nomenclature of Ionic Compounds of Monatomic Ions (Both Fixed & Variable Charges)

FORMULA	NAME
	sodium oxide
	magnesium nitride
	copper(I) sulfide
	manganese(II) iodide
	iron(III) phosphide
	copper(I) oxide
	tin(II) nitride
	strontium oxide
	tin(IV) oxide
	nickel chloride

FORMULA	NAME
KBr	
$FeBr_2$	
PbS	
BaO	
K_2O	
$CrBr_3$	
Fe_3P_2	
Li_2S	
$CuCl_2$	
AgF	

Check your answers to the above drill before going on. If you have made any mistakes be sure you find out why before you continue to the next drill. If necessary you should review all the previous Units.

Extra Drill H: Nomenclature of Ionic Compounds of Monatomic Ions (Both Fixed & Variable Charges)

FORMULA	NAME
$RaCl_2$	
$CrCl_3$	
Fe_2O_3	
$MgBr_2$	
MnO	
MnO_2	

Unit V: Nomenclature of Polyatomic Ions

Unit VA: The "Basic Eight" Polyatomic Ions

In this unit you are asked to memorize the names and formulas of 8 polyatomic ions, *to start with*. You will be asked to learn more later on. "Learning" means memorizing the correct spelling of the name, the correct subscript(s) and charge of each ion.

1+	**1–**	**2–**	**3–**
NH_4^+ **ammonium**	$C_2H_3O_2^-$ **acetate***	CO_3^{2-} **carbonate**	PO_4^{3-} **phosphate**
	NO_3^- **nitrate**	SO_4^{2-} **sulfate**	
	OH^- **hydroxide**		
	ClO_3^- **chlorate**		

*acetate is also written as $CH_3CO_2^-$

In memorization, it helps to look for patterns. Note that all but two of the ions have the ending "–ate". For the ions with a charge of 1–, look up where the first element of each ion is located on the period table (C, N, O, Cl). Study the formulas and names of this group of ions before moving on to ions with a charge of 2–. Again look up the location of the first element of each ion in the periodic table (C and S). Study these two names and formulas, and finally move to the ion with a charge of 3–. Look up the position of P in the periodic table. After you have studied each group based on charges, put them on flash cards and test yourself over and over. You **MUST** know these 8 polyatomic ions backwards and forwards before you proceed to the next unit.

Drill I - 1: Nomenclature of the "Basic Eight" Polyatomic Ions

NAME	FORMULA	FORMULA	NAME
sulfate		$\mathbf{OH^-}$	
acetate		$\mathbf{SO_4^{2-}}$	
chlorate		$\mathbf{NH_4^+}$	
ammonium		$\mathbf{NO_3^-}$	
phosphate		$\mathbf{ClO_3^-}$	
carbonate		$\mathbf{PO_4^{3-}}$	
hydroxide		$\mathbf{CO_3^{2-}}$	
nitrate		$\mathbf{C_2H_3O_2^-}$	

Drill I - 2: Nomenclature of Compounds of the "Basic Eight" Polyatomic Ions With Cations of Fixed Charges:

NAME	FORMULA	FORMULA	NAME
sodium carbonate		K_3PO_4	
strontium carbonate		$Ca(NO_3)_2$	
aluminum sulfate		$(NH_4)_2SO_4$	
ammonium phosphate		$Al(OH)_3$	
aluminum chlorate		$LiC_2H_3O_2$	
potassium sulfate		$MgCO_3$	
calcium acetate		$Ba(ClO_3)_2$	
nickel carbonate		$AgNO_3$	

Drill I - 3: Nomenclature of Compounds of the "Basic Eight" Polyatomic Ions With Cations of Variable Charges:

NAME	FORMULA	FORMULA	NAME
iron(II) carbonate		Cu_2CO_3	
iron(III) carbonate		$CuCO_3$	
copper(I) sulfate		$SnSO_4$	
cobalt(II) phosphate		$Fe_3(PO_4)_2$	
chromium(III) chlorate		$Hg(C_2H_3O_2)_2$	
tin(IV) sulfate		$FePO_4$	
chromium(II) acetate		$Mn(ClO_3)_2$	

Drill I - 4: Compounds of the "Basic Eight" Polyatomic Ions and –ide ions With Cations of Both Fixed and Variable Charges: (This helps you learn to distinguish between those that require Roman numerals and those that do not.)

NAME	FORMULA	FORMULA	NAME
calcium phosphate		Na_3N	
chromium(III) sulfide		$NaNO_3$	
potassium carbonate		K_2SO_4	
magnesium acetate		$HgCO_3$	
chromium(III) hydroxide		$FeCl_2$	
aluminum chlorate		$FeCl_2$	
lead(IV) selenide		NH_4NO_3	
copper(II) nitride		$Mn(ClO_3)_2$	
silver oxide		$Zn(C_2H_3O_2)_2$	

Unit VB: Polyatomic Ions with "–ite" Ending

In the previous unit (Unit VA) you learned six polyatomic ions with the "–ate" ending. Certain of these have counterparts with the "–ite" ending. The only difference in formula for those with "–ite" endings is in having one less oxygen. The charge is unchanged. For example, nitr*ate* is NO_3^- and nitr*ite* is NO_2^-. Below are the ones with which you should become familiar.

NO_3^- nitrate	**SO_4^{2-} sulfate**	**PO_4^{3-} phosphate**
NO_2^- nitrite	**SO_3^{2-} sulfite**	**PO_3^{3-} phosphite**

ClO_3^- chlorate
ClO_2^- chlorite

Unit VC: Nomenclature of "–ate" and "–ite" Compounds

The rules for naming and writing formulas for polyatomic ions are the same as for the monatomic ions (see Unit VI). The only difference is if (and only if) there is more than one polyatomic ion, parenthesis must be used to avoid confusion.

For example, magnesium nitrite is $Mg(NO_2)_2$. Since Mg is in Group IIA, it has a charge of **2+** and nitrite has a charge of **1–** (from memory), to obtain a net charge of zero, there must be *two* nitrite ions for every magnesium ion. In the case of potassium acetate, since potassium is in Group IA, it must have a charge of **1+**, and acetate has a charge of **1–**, the formula is simply $KC_2H_3O_2$. No parenthesis is necessary.

In naming compounds with cations of variable charges, the charge of the cation must be deduced from the charge of the anions. It is therefore imperative that you have learned the charges of the ions presented in Units VA and VB. For example, $MnSO_4$ should be named manganese(II) sulfate. Since you had previously memorized the fact that SO_4^{2-} has a charge of **2–**, the manganese ion must have a charge of **2+**. In the case of $Cu(NO_3)_2$, since the nitrate ion has a charge of **1–**, two nitrates would have a total charge of **2–**. Thus Cu must have a charge of **2+**. The name for $Cu(NO_3)_2$ is therefore Cu(II) nitrate or cupric nitrate.

Drill I-5: Nomenclature of "–ate" and "–ite" ions and compounds

FORMULA	NAME
SO_4^{2-}	
SO_3^{2-}	
	nitrite
	phosphite
	acetate
	chlorite
Na_3PO_4	
K_2SO_3	
$Pb(OH)_2$	
$CoClO_2$	
$Ca(NO_3)_2$	
	iron(III) carbonate
	copper(I) sulfite
	lithium nitrite
	aluminum chlorate

Unit VD: Nomenclature of Oxohalo Anions

These are the anions that contain a halogen and various number of oxygen atoms. In this unit we will focus on the chlorine series. Note that all have the charge of 1–. Starting with chlorate which is one of our "Basic Eight" from Unit VA, when we lose one oxygen, we get the one with the –ite ending. When we lose *another* oxygen, the name picks up the prefix *hypo*. When we lose *yet another* oxygen, there is no oxygen left and we have the simple monatomic ion with the –ide ending (from Unit III). Returning to chlorate as the base, if we *add* one extra oxygen, the name picks up the prefix *per.*

ClO_4^-	**perchlorate**
ClO_3^-	***chlorate***
ClO_2^-	**chlorite**
ClO^-	**hypochlorite**
Cl^-	**chloride**

Drill J: Nomenclature of Oxohalo Anions and Compounds:

FORMULA	NAME
ClO^-	
ClO_2^-	
ClO_4^-	
	hypochlorite
	chlorate
	perchlorate
	chlorite
	chloride
	sodium chlorite
	magnesium chlorite
	iron(II) perchlorate
	nickel hypochlorite

Note that once you have learned the above oxo*chloro* anions, you are just one step away from learning the corresponding oxo*bromo* and oxo*iodo* anions. Dr. Yau does not expect you to learn the following, but please note bromine and iodine follow the same rules as Cl. You will learn these for General Chemistry.

perbromate, bromate, bromite, hypobromite, bromide

BrO_4^- BrO_3^- BrO_2^- BrO^- Br^-

periodate, iodate, iodite, hypoiodite, iodide

IO_4^- IO_3^- IO_2^- IO^- I^-

Drill K: Nomenclature of "–ate", "–ite", oxohaloanions & Their Compounds

FORMULA	NAME
ClO_4^-	
ClO_3^-	
ClO_2^-	
ClO^-	
Cl^-	
	nitrite
	nitrate
	nitride
	hydroxide
$Ca(ClO)_2$	
$Ca_3(PO_3)_2$	
$Mn(OH)_2$	
$Fe(NO_3)_3$	
$Hg(ClO)_2$	
K_3N	
	potassium perchlorate
	potassium sulfite
	aluminum sulfide
	sodium sulfate
	barium hydroxide
	ammonium carbonate
	copper(I) hypochlorite
	tin(IV) acetate
	chromium(III) phosphite
	magnesium chlorate
	zinc phosphide
	calcium nitrite

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Unit VI: Nomenclature of Acids

The system of naming acids presented in this unit relies on how well you know the formulas of the polyatomic ions. If necessary review all of the above units.

Starting with a polyatomic ion (such as SO_4^{2-}), add as many $\mathbf{H^+}$ as necessary to neutralize the charge. For sulfate, with a charge of 2–, you would have to add two $\mathbf{H^+}$. Generally the hydrogen is placed at the front of the formula (H_2SO_4). For phosphate, you would have to add three H^+, and the acid has the formula of H_3PO_4.

The name of the acid depends on the ending of the anion. If the ending is –ate, the corresponding acid has the ending –ic acid. If the ending is –ite, the corresponding acid has the ending –ous acid. If the ending is –ide, the acid has the *prefix* of hydro– and an ending of –ic acid.

Ending of Anion	Name of Corresponding Acid
–ate	–ic acid
–ite	–ous acid
–ide	hydro–….–ic acid

Thus, sulfate becomes sulfur*ic acid*; sulfite becomes sulfur*ous acid* and sulfide becomes *hydro*sulfur*ic acid.*

Drill L: Nomenclature of Acids

ANIONS		**CORRESPONDING ACIDS**	
Formula	**Name**	**Formula**	**Name**
ClO_4^-	______	______	______
ClO_3^-	______	______	______
ClO_2^-	______	______	______
ClO^-	______	______	______
Cl^-	______	______	______
Br^-	______	______	______
I^-	______	______	______
$C_2H_3O_2^-$	______	______	______
NO_3^-	______	______	______
NO_2^-	______	______	______
OH^-	______	______	______
ClO_3^-	______	______	______
CO_3^{2-}	______	______	______
SO_4^{2-}	______	______	______
SO_3^{2-}	______	______	______
PO_4^{3-}	______	______	______
PO_3^{3-}	______	______	______

Drill continues on following page

(Continuation of Drill L)

Name	Formula	Formula	Name
sulfuric acid		**HNO_3**	
nitrous acid		**H_2CO_3**	
hydrochloric acid		**H_3PO_3**	
carbonic acid		**HClO**	
phosphorous acid		**H_2SO_4**	
chlorous acid		**$HC_2H_3O_2$**	
sulfurous acid		**HNO_2**	
hypochlorous acid		**$HClO_4$**	
chloric acid		**HBr**	
phosphoric acid		**H_2SO_3**	
nitric acid		**H_2S**	
acetic acid		**H_3PO_4**	
hydrosulfuric acid		**HOH**	

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Unit VII: Nomenclature of Acid Anions

In Unit VI you learned that acids generally have one or more H at the front of the formula. It does not have a charge because we have added as many $\mathbf{H^+}$ as necessary to keep it neutral. An "acid anion", however, by definition must have a H in front (to be called an *acid*), as well as a negative charge (to be called an *anion*). It is derived from having added *less* than the necessary number of $\mathbf{H^+}$.

For example, if we add only one $\mathbf{H^+}$ to the sulfate ion (SO_4^{2-}), we would have the acid anion, HSO_4^-. If we add only one $\mathbf{H^+}$ to the phosphite ion (PO_3^{3-}), we would have the acid anion HPO_3^{2-}. If we added two, we would have the acid anion $H_2PO_3^-$. Note that the negative charge of the anion is reduced by each additional $\mathbf{H^+}$.

Study the following names and formulas and then test yourself using flash cards:

CO_3^{2-} carbonate
HCO_3^- hydrogen carbonate or bicarbonate
SO_4^{2-} sulfate
HSO_4^- hydrogen sulfate or bisulfate
SO_3^{2-} sulfite
HSO_3^- hydrogen sulfite or bisulfite

PO_4^{3-} phosphate	PO_3^{3-} phosphite
HPO_4^{2-} hydrogen phosphate	HPO_3^{2-} hydrogen phosphite
$H_2PO_4^-$ dihydrogen phosphate	$H_2PO_3^-$ dihydrogen phosphite

Remember! The prefix "bi" in naming acid anions does <u>NOT</u> mean "2!"
When it appears in the name of an acid anion, it means there is <u>ONE</u> H^+ has been added.
Add one H in front of the formula of the acid anion, and add +1 to the negative charge.
SO_4^{2-} becomes HSO_4^-.

NAMING COMPOUNDS WITH ACID ANIONS

1. Isolate the acid anion and figure out the charge of the acid anion.
   e.g. In $Sn(HSO_3)_2$ the acid anion is HSO_3 with a charge of –1.
2. Determine the total charge of all the acid anions.
   e.g. In $Sn(HSO_3)_2$ the total charge of the acid anions would be –2 (two HSO_3^-).
3. Since the total charge of the compound must add up to zero, you can now determine the charge of the cation. (e.g. Sn in $Sn(HSO_3)_2$ must have a charge of +2, so it is tin(II).) Name of $Sn(HSO_3)_2$ is therefore tin(II) hydrogensulfite or tin(II) bisulfate (common name).

Drill M: Nomenclature of Acid Anions

	Formula	Stock Name	Common Name (when appropriate)
1	$Ca(HCO_3)_2$		
2	$Fe(HCO_3)_2$		
3	$Pb(HPO_4)_2$		xxxxxxxxxxxxxxxxx
4	$AgHSO_3$		
5	$Fe(H_2PO_3)_3$		xxxxxxxxxxxxxxxxx
6		barium hydrogen phosphate	xxxxxxxxxxxxxxxxx
7		magnesium hydrogen sulfite	
8		aluminum hydrogen phosphate	xxxxxxxxxxxxxxxxx
9		mercury(II) dihydrogen phosphite	xxxxxxxxxxxxxxxxx
10		zinc hydrogen carbonate	
11			barium bisulfite
12			iron(III) bicarbonate
13			copper(I) bisulfate
14			copper(II) dihydrogen phosphite
15		tin(IV) hydrogen phosphate	xxxxxxxxxxxxxxxxx
16		iron(III) hydrogen phosphite	xxxxxxxxxxxxxxxxx

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Unit VIII: Nomenclature of Molecular Binary Compounds

Units III through VIII dealt with *ions* and *ionic* compounds. In this unit we will deal with *molecular* compounds. In particular, the molecular *binary* compounds, compounds containing only two *nonmetals*. They involve a completely different set of rules. Since there are no ions, there are no charges and no Roman numerals.

The number of atoms of each element is specified by a Greek *prefix* (see table below). The second element has the ending "−ide". For example, N_2F_4 is named dinitrogen tetrafluoride.

When two vowels are adjacent to each other, one is dropped. For example P_2O_5 is named diphosphorus *pentoxide* rather than *pentaoxide*.

When the first element has only one atom, the prefix *mono* is often omitted. For example, NO_2 is often referred to as nitrogen dioxide rather than mononitrogen dioxide.

When the second element has only one atom, the prefix *mono* is retained. For example, CO is carbon monoxide rather than monocarbon monoxide.

Number	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta

Number	Prefix
6	hexa
7	hepta
8	octa
9	nona
10	deca

Drill N: Nomenclature of Molecular Binary Compounds

FORMULA	NAME
CBr_4	
PCl_5	
S_2Br_2	
N_2O_4	
	sulfur dioxide
	diiodine trioxide
	dibromine monoxide

Remember that the rules stated here for using prefixes (mono, di, tri, etc.) are for ***molecular*** binary compounds. That excludes ***ionic compounds***! For ionic compounds you follow the rules you have learned from Units III through VIII earlier in this tutorial. Thus PCl_3 is phosphorus trichloride, but $AlCl_3$ is aluminum chloride and $MnCl_3$ is manganese(III) chloride. You have already learned all the rules (when to use prefixes, when to use Roman numerals and when not to use either). The drill below is to help you practise choosing the appropriate rules to follow.

The key is to first determine whether a compound is molecular or ionic. That is easily done by seeing whether the first element shown is a metal or nonmetal. There are exceptions to this rule, but for now, let us consider only the usual cases. If the compound is molecular, you use prefixes. If it is ionic, you must decide whether the cation has fixed or variable charges in order to determine whether or not to use Roman numerals (Unit III).

Drill O: Drill in Determining When to Use Prefixes and Roman Numerals

FORMULA	**NAME**
$PbCl_2$	
SCl_2	
$MgCl_2$	
Co_2S_3	
Al_2O_3	
N_2Br_4	
K_3P	

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Unit IX: Nomenclature of Hydrates

A hydrate is a compound with a fixed number of water molecules as an integral part of its structure. An example is $CuSO_4{\cdot}5H_2O$, a blue crystalline material. As the formula indicates, it has five water molecules for each unit of $CuSO_4$. Although it contains water molecules, it is a solid.

Note that a hydrate is not simply a sample that is wet! A wet sample would have a variable amount of water and would not have the fixed ratio of water attached.

In naming hydrates, you would name the compound with the rules that you have learned previously, followed by specifying how many water molecules are attached with a prefix.

Thus, $CuSO_4 \cdot 5H_2O$ is named copper(II) sulfate pentahydrate, and cobalt(II) chloride tetrahydrate has the formula $CoCl_2 \cdot 4H_2O$.

Note that the dot in front of the formula H_2O does <u>not</u> represent a multiplication sign! It merely separates out the H_2O from the rest of the formula and the coefficient in front of the H_2O tells you how many water molecules are present. $CoCl_2 \cdot 4H_2O$, therefore, contains one Co^{2+} ion, two Cl^- ions and four water molecules. It has a total of one cobalt, two chlorine, eight hydrogen and four oxygen atoms.

<u>Drill P: Drill on Naming Hydrates</u>

Formula	**Name**	**Name**	**Formula**
$Ca(ClO_3)_2 \cdot 2H_2O$		cobalt(II) fluoride tetrahydrate	
$Sn(SO_4)_2 \cdot 2H_2O$		zinc acetate dihydrate	
$NiSO_4 \cdot 7H_2O$		copper(II) nitrate trihydrate	
$Co(C_2H_3O_2)_2 \cdot 4H_2O$		iron(III) bromide hexahydrate	

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End of Nomenclature Tutorial
(See the following pages for the answers to the drills.)

If you have questions or comments you may contact me at cyau@ccbcmd.edu

Answers to "Nomenclature: A Tutorial"

Drill A: Nomenclature of Elements

Name	Symbol
chlorine	*Cl*
calcium	*Ca*
arsenic	*As*
mercury	*Hg*
copper	*Cu*

Symbol	Name
S	*sulfur*
K	*potassium*
Fe	*iron*
Na	*sodium*
P	*phosphorus*

Drill B: Formulas and Physical States of Pure Elements

chlorine	Cl_2 (*g*)
argon	Ar (*g*)
nitrogen	N_2 (*g*)
chromium	Cr (*s*)
strontium	Sr (*s*)

bromine	Br_2 (*l*)
phosphorus	P_4 (*s*)
krypton	Kr (*g*)
mercury	Hg (*l*)
iodine	I_2 (*s*)

sulfur	S_8 (*s*)
lead	Pb (*s*)
element #109	Mt (*s*)
arsenic	As (*s*)
hydrogen	H_2 (*g*)

Drill C: Nomenclature of Monatomic Ions

FORMULA	NAME
Rb^+	*rubidium ion*
Ba^{2+}	*barium ion*
P^{3-}	*phosphide*
Br^-	*bromide*
N^{3-}	*nitride*
S^{2-}	*sulfide*
Hg^{2+}	*mercury(II) ion*
Cu^{2+}	*copper(II) ion*
Ca	*calcium*
Ni^{2+}	*nickel ion or nickel(II) ion*

NAME	FORMULA
nitride	N^{3-}
iodide	I^-
oxide	O^{2-}
chromium(III)	Cr^{3+}
potassium ion	K^+
aluminum ion	Al^{3+}
magnesium	*Mg*
ferrous ion	Fe^{2+}
copper(I) ion	Cu^+
zinc ion	Zn^{2+}

Note that some of the cations required Roman numerals, and some do not! Remember that Ni^{2+} and Zn^{2+} are two of the unusual cations that have fixed charges even though they are not from the Group IA, IIA families. You should review which other cations are in this category.

Drill D: Formulas of Ionic Compounds of Monatomic ions

NAME	FORMULA
magnesium fluoride	MgF_2
lithium sulfide	Li_2S
calcium selenide	$CaSe$
nickel fluoride	NiF_2
copper(II) bromide	$CuBr_2$
chromium(III) sulfide	Cr_2S_3
tin(II) phosphide	Sn_3P_2

Drill E: Writing Names of Compounds with Cations of Fixed Charges

KBr	*potassium bromide*
Li_2O	*lithium oxide*
Mg_3As_2	*magnesium arsenide*
Na_3P	*sodium phosphide*

Drill F: Determining the Charge and Name of the Cation First, Then Name of Compound

Formula	Charge of Cation	Name of Cation	Name of Compound
MnO_2	*4+*	*manganese(IV) ion*	*manganese(IV) oxide*
PbS	*2+*	*lead(II) ion*	*lead(II) sulfide*
Cr_2O_3	*3+*	*chromium(III) ion*	*chromium(III) oxide*
K_2S	*1+*	*potassium ion*	*potassium sulfide (no Roman numeral)*
$CuCl_2$	*2+*	*copper(II) ion*	*copper(II) chloride*
CuO	*2+*	*copper(II) ion*	*copper(II) oxide*
Cu_2O	*1+*	*copper(I) ion*	*copper(I) oxide*
ZnO	*2+*	*zinc ion* *or zinc(II) ion*	*zinc oxide* *or zinc(II) oxide*

Drill G: Nomenclature of Ionic Compounds of Monatomic Ions
(Both Fixed & Variable Charges)

FORMULA	NAME
Na_2O	sodium oxide
Mg_3N_2	magnesium nitride
Cu_2S	copper(I) sulfide
MnI_2	manganese(II) iodide
FeP	iron(III) phosphide
Cu_2O	copper(I) oxide
Sn_3N_2	tin(II) nitride
SrO	strontium oxide
SnO_2	tin(IV) oxide
$NiCl_2$	nickel chloride

FORMULA	NAME
KBr	*potassium bromide*
$FeBr_2$	*iron(II) bromide*
PbS	*lead(II) sulfide*
BaO	*barium oxide*
K_2O	*potassium oxide*
$CrBr_3$	*chromium(III) bromide*
Fe_3P_2	*iron(II) phosphide*
Li_2S	*lithium sulfide*
$CuCl_2$	*copper(II) chloride*
AgF	*silver fluoride* *or silver(I) fluoride*

Extra Drill H: Nomenclature of Ionic Compounds of Monatomic Ions
(Both Fixed & Variable Charges)

FORMULA	NAME
$RaCl_2$	*radium chloride*
$CrCl_3$	*chromium(III) chloride*
Fe_2O_3	*iron(III) oxide*
$MgBr_2$	*magnesium bromide*
MnO	*manganese(II) oxide*
MnO_2	*manganese(IV) oxide*

Drill I - 1: Nomenclature of the "Basic Eight" Polyatomic Ions

NAME	FORMULA	FORMULA	NAME
sulfate	*SO_4^{2-}*	**OH^-**	***hydroxide***
acetate	*$C_2H_3O_2^-$*	**SO_4^{2-}**	***sulfate***
chlorate	*ClO_3^-*	**NH_4^+**	***ammonium***
ammonium	*NH_4^+*	**NO_3^-**	***nitrate***
phosphate	*PO_4^{3-}*	**ClO_3^-**	***chlorate***
carbonate	*CO_3^{2-}*	**PO_4^{3-}**	***phosphate***
hydroxide	*OH^-*	**CO_3^{2-}**	***carbonate***
nitrate	*NO_3^-*	**$C_2H_3O_2^-$**	***acetate***

Drill I - 2: Nomenclature of Compounds of the "Basic Eight" Polyatomic Ions With Cations of Fixed Charges:

NAME	FORMULA	FORMULA	NAME
sodium carbonate	*Na_2CO_3*	**K_3PO_4**	***potassium phosphate***
strontium carbonate	*$SrCO_3$*	**$Ca(NO_3)_2$**	***calcium nitrate***
aluminum sulfate	*$Al_2(SO_4)_3$*	**$(NH_4)_2SO_4$**	***ammonium sulfate***
ammonium phosphate	*$(NH_4)_3PO_4$*	**$Al(OH)_3$**	***aluminum hydroxide***
aluminum chlorate	*$Al(ClO_3)_3$*	**$LiC_2H_3O_2$**	***lithium acetate***
potassium sulfate	*K_2SO_4*	**$MgCO_3$**	***magnesium carbonate***
calcium acetate	*$Ca(C_2H_3O_2)_2$*	**$Ba(ClO_3)_2$**	***barium chlorate***
nickel carbonate	*$NiCO_3$*	**$AgNO_3$**	***silver nitrate or silver(I) nitrate***

Drill I - 3: Nomenclature of Compounds of the "Basic Eight" Polyatomic Ions with Cations of Variable Charges:

NAME	FORMULA	NAME	FORMULA
iron(II) carbonate	*$FeCO_3$*	**Cu_2CO_3**	***copper(I) carbonate***
iron(III) carbonate	*$Fe_2(CO_3)_3$*	**$CuCO_3$**	***copper(II) carbonate***
copper(I) sulfate	*Cu_2SO_4*	**$SnSO_4$**	***tin(II) sulfate***
cobalt(II) phosphate	*$Co_3(PO_4)_2$*	**$Fe_3(PO_4)_2$**	***iron(II) phosphate***
chromium(III) chlorate	*$Cr(ClO_3)_3$*	**$Hg(C_2H_3O_2)_2$**	***mercury(II) acetate***
tin(IV) sulfate	*$Sn(SO_4)_2$*	**$FePO_4$**	***iron(III) phosphate***
chromium(II) acetate	*$Cr(C_2H_3O_2)_2$ or $Cr(CH_3CO_2)_2$*	**$Mn(ClO_3)_2$**	***manganese(II) chlorate***

Can you figure out why $FePO_4$ is iron(III) phosphate and note iron(IV) phosphate?

Drill I - 4: Compounds of the "Basic Eight" Polyatomic Ions and –ide ions With Cations of Both Fixed and Variable Charges:

(learning to distinguish between those that require Roman numerals and those that do not)

NAME	FORMULA	FORMULA	NAME
calcium phosphate	$Ca_3(PO_4)_2$	Na_3N	*sodium nitride*
chromium(III) sulfide	Cr_2S_3	$NaNO_3$	sodium nitrate
potassium carbonate	K_2CO_3	K_2SO_4	potassium sulfate
magnesium acetate	$Mg(CH_3CO_2)_2$	$HgCO_3$	mercury(II) carbonate
chromium(III) hydroxide	$Cr(OH)_3$	$FeCl_2$	*iron(II) chloride*
aluminum chlorate	$Al(ClO_3)_3$	$FeCl_3$	*iron(III) chloride*
lead(IV) selenide	$PbSe_2$	NH_4NO_3	*ammonium nitrate*
copper(II) nitride	Cu_3N_2	$Mn(ClO_3)_2$	*manganese(II) chlorate*
silver oxide	Ag_2O	$Zn(C_2H_3O_2)_2$	*zinc acetate* *or zinc(II) acetate*

Drill I-5: Nomenclature of "–ate" and "–ite" ions and compounds

FORMULA	NAME
SO_4^{2-}	*sulfate*
SO_3^{2-}	*sulfite*
NO_2^{-}	nitrite
PO_3^{3-}	phosphite
$C_2H_3O_2^{-}$	acetate
ClO_2^{-}	chlorite
Na_3PO_4	*sodium phosphate*
K_2SO_3	*potassium sulfite*
$Pb(OH)_2$	*lead(II) hydroxide*
$CoClO_2$	*cobalt(I) chlorite*
$Ca(NO_3)_2$	*calcium nitrate*
$Fe_2(CO_3)_3$	iron(III) carbonate
Cu_2SO_3	copper(I) sulfite
$LiNO_2$	lithium nitrite
$Al(ClO_3)_3$	aluminum chlorate

Drill J: Nomenclature of Oxohalo Ions and Compounds:

FORMULA	NAME
ClO^-	*hypochlorite*
ClO_2^-	*chlorite*
ClO_4^-	*perchlorate*
ClO^-	hypochlorite
ClO_3^-	chlorate
ClO_4^-	perchlorate
ClO_2^-	chlorite
Cl^-	chloride
$NaClO_2$	sodium chlorite
$Mg(ClO_2)_2$	magnesium chlorite
$Fe(ClO_4)_2$	iron(II) perchlorate
$Ni(ClO)_2$	nickel hypochlorite

Drill K: Nomenclature of "–ate", "–ite", oxohaloanions & Their Compounds:

FORMULA	NAME
ClO_4^-	*perchlorate*
ClO_3^-	*chlorate*
ClO_2^-	*chlorite*
ClO^-	*hypochlorite*
Cl^-	*chloride*
NO_2^-	nitrite
NO_3^-	nitrate
N^{3-}	nitride
OH^-	hydroxide
$Ca(ClO)_2$	*calcium hypochlorite*
$Ca_3(PO_3)_2$	*calcium phosphite*
$Mn(OH)_2$	*manganese(II) hydroxide*
$Fe(NO_3)_3$	*iron(III) nitrate*
$Hg(ClO)_2$	*mercury(II) hypochlorite*
K_3N	*potassium nitride*
$KClO_4$	potassium perchlorate
K_2SO_3	potassium sulfite
Al_2S_3	aluminum sulfide
Na_2SO_4	sodium sulfate
$Ba(OH)_2$	barium hydroxide
$(NH_4)_2CO_3$	ammonium carbonate
$CuClO$	copper(I) hypochlorite
$Sn(C_2H_3O_2)_4$	tin(IV) acetate
$CrPO_3$	chromium(III) phosphite
$Mg(ClO_3)_2$	magnesium chlorate
Zn_3P_2	zinc phosphide
$Ca(NO_2)_2$	calcium nitrite

Drill L: Nomenclature of Acids

ANIONS		CORRESPONDING ACIDS	
Formula	**Name**	**Formula**	**Name**
ClO_4^-	*perchlorate*	$HClO_4$	*perchloric acid*
ClO_3^-	*chlorate*	$HClO_3$	*chloric acid*
ClO_2^-	*chlorite*	$HClO_2$	*chlorous acid*
ClO^-	*hypochlorite*	$HClO$	*hypochlorous acid*
Cl^-	*chloride*	HCl	*hydrochloric acid*
Br^-	*bromide*	HBr	*hydrobromic acid*
I^-	*iodide*	HI	*hydroiodic acid*
$C_2H_3O_2^-$	*acetate*	$HC_2H_3O_2$	*acetic acid*
NO_3^-	*nitrate*	HNO_3	*nitric acid*
NO_2^-	*nitrite*	HNO_2	*nitrous acid*
OH^-	*hydroxide*	HOH	*water*
ClO_3^-	*chlorate*	$HClO_3$	*chloric acid*
CO_3^{2-}	*carbonate*	H_2CO_3	*carbonic acid*
SO_4^{2-}	*sulfate*	H_2SO_4	*sulfuric acid*
SO_3^{2-}	*sulfite*	H_2SO_3	*sulfurous acid*
PO_4^{3-}	*phosphate*	H_3PO_4	*phosphoric acid*
PO_3^{3-}	*phosphite*	H_3PO_3	*phosphorous acid*

Continuation of Drill L

Name	Formula	Formula	Name
sulfuric acid	***H_2SO_4***	**HNO_3**	***nitric acid***
nitrous acid	***HNO_2***	**H_2CO_3**	***carbonic acid***
hydrochloric acid	***HCl***	**H_3PO_3**	***phosphorous acid***
carbonic acid	***H_2CO_3***	**$HClO$**	***hypochlorous acid***
phosphorous acid	***H_3PO_3***	**H_2SO_4**	***sulfuric acid***
chlorous acid	***$HClO_2$***	**$HC_2H_3O_2$**	***acetic acid***
sulfurous acid	***H_2SO_3***	**HNO_2**	***nitrous acid***
hypochlorous acid	***$HClO$***	**$HClO_4$**	***perchloric acid***
chloric acid	***$HClO_3$***	**HBr**	***hydrobromic acid***
phosphoric acid	***H_3PO_4***	**H_2SO_3**	***sulfurous acid***
nitric acid	***HNO_3***	**H_2S**	***hydrosulfuric acid***
acetic acid	***$HC_2H_3O_2$***	**H_3PO_4**	***phosphoric acid***
hydrosulfuric acid	***H_2S***	**HOH**	***water***

Drill M: Nomenclature of Acid Anions

1. ***calcium hydrogen carbonate, calcium bicarbonate***
2. ***iron(II) hydrogen carbonate, iron(II) bicarbonate or ferrous bicarbonate***
3. ***lead(IV) hydrogen phosphate***
4. ***silver hydrogen sulfite, silver bisulfite***
5. ***iron(III) dihydrogen phosphite***
6. ***$BaHPO_4$***
7. ***$Mg(HSO_3)_2$, magnesium bisulfite***
8. ***$Al_2(HPO_4)_3$***
9. ***$Hg(H_2PO_3)_2$***
10. ***$Zn(HCO_3)_2$, zinc(II) bicarbonate***
11. ***$Ba(HSO_3)_2$, barium hydrogen sulfite***
12. ***$Fe(HCO_3)_3$, iron(III) hydrogen carbonate***
13. ***$CuHSO_4$, copper(I) hydrogen sulfate***
14. ***$Cu(H_2PO_3)_2$, copper(II) dihydrogen phosphite***
15. ***$Sn(HPO_4)_2$***
16. ***$Fe_2(HPO_3)_3$***

Drill N: Nomenclature of Molecular Binary Compounds

FORMULA	NAME
CBr_4	***carbon tetrabromide***
PCl_5	***phosphorus pentachloride***
S_2Br_2	***disulfur dibromide***
N_2O_4	***dinitrogen tetroxide***
SO_2	**sulfur dioxide**
I_2O_3	**diiodine trioxide**
Br_2O	**dibromine monoxide**

Drill O: Drill in Determining When to Use Prefixes and Roman Numerals

FORMULA	NAME
$PbCl_2$	***lead(II) chloride*** *(ionic, cation with variable charges)*
SCl_2	***sulfur dichloride*** *(molecular)*
$MgCl_2$	***magnesium chloride*** *(ionic, cation with fixed charges)*
Co_2S_3	***cobalt(III) sulfide*** *(ionic, cation with variable charges)*
Al_2O_3	***aluminum oxide*** *(ionic, cation with fixed charges)*
N_2Br_4	***dinitrogen tetrabromide*** *(molecular)*
K_3P	***potassium phosphide*** *(ionic, cation with fixed charges)*

Drill P: Drill on Naming Hydrates

Formula	Name	Name	Formula
$Ca(ClO_3)_2{\cdot}2H_2O$	*calcium chlorate dihydrate*	cobalt(II) fluoride tetrahydrate	***$CoF_2{\cdot}4H_2O$***
$Sn(SO_4)_2{\cdot}2H_2O$	*tin(IV) sulfate dihydrate*	zinc acetate dihydrate	***$Zn(C_2H_3O_2)_2{\cdot}2H_2O$***
$NiSO_4{\cdot}7H_2O$	*nickel sulfate heptahydrate*	copper(II) nitrate trihydrate	***$Cu(NO_3)_2{\cdot}3H_2O$***
$Co(C_2H_3O_2)_2{\cdot}4H_2O$	*cobalt(II) acetate tetrahydrate*	iron(III) bromide hexahydrate	***$FeBr_3{\cdot}6H_2O$***

End of Answers to the Nomenclature Tutorial Drills

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